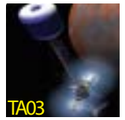
National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS


TA01


TA02


TA03


TA04


TA05


TA06

TA01 · LAUNCH PROPULSION SYSTEMS

Solid Rocket Propulsion Systems
- Propellants
- Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

Liquid Rocket Propulsion Systems
- LH_2/LOX Based
- RP/LOX Based
- CH_4/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

Air Breathing Propulsion Systems
- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

Ancillary Propulsion Systems
- Auxiliary Control Systems
- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Sensors
- Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

Unconventional / Other Propulsion Systems
- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Assist
- Beamed Energy / Energy Addition
- Nuclear
- High Energy Density Materials/Propellants

TA02 · IN-SPACE PROPULSION TECHNOLOGIES

Chemical Propulsion
- Liquid Storable
- Liquid Cryogenic
- Gels
- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

Non-Chemical Propulsion
- Electric Propulsion
- Solar Sail Propulsion
- Thermal Propulsion
- Tether Propulsion

Advanced (TRL <3) Propulsion Technologies
- Beamed Energy Propulsion
- Electric Sail Propulsion
- Fusion Propulsion
- High Energy Density Materials
- Antimatter Propulsion
- Advanced Fission
- Breakthrough Propulsion

Supporting Technologies
- Propellant Storage & Transfer

TA03 · SPACE POWER & ENERGY STORAGE

Power Generation
- Energy Harvesting
- Chemical (Fuel Cells, Heat Engines)
- Solar (Photo-Voltaic & Thermal)
- Radioisotope
- Fission
- Fusion

Energy Storage
- Batteries
- Flywheels
- Regenerative Fuel Cells

Power Management & Distribution
- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

Cross Cutting Technology
- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 · ROBOTICS, TELE-ROBOTICS&AUTONOMOUS SYSTEMS

Sensing & Perception
- 3-D Perception
- Relative Position & Velocity Estimation
- Terrain Mapping, Classification & Characterization
- Natural & Man-made Object Recognition
- Sensor Fusion for Sampling & Manipulation
- Onboard Science Data Analysis

Mobility
- Extreme Terrain Mobility
- Below-Surface Mobility
- Above-Surface Mobility
- Small Body/Microgravity Mobility

Manipulation
- Robot Arms
- Dexterous Manipulators
- Modeling of Contact Dynamics
- Mobile Manipulation
- Collaborative Manipulation
- Robotic Drilling & Sample Processing

Human-Systems Integration
- Multi-Modal Human-Systems Interaction
- Supervisory Control
- Robot-to-Suit Interfaces
- Intent Recognition & Reaction
- Distributed Collaboration
- Common Human-Systems Interfaces
- Safety, Trust, & Interfacing of Robotic/ Human Proximity Operations

Autonomy
- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy
- Terrain Relative Navigation
- Path & Motion Planning with Uncertainty

Autonomous Rendezvous & Docking
- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces
- Mission/System Managers for Autonomy/Automation

RTA Systems Engineering
- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

Optical Comm. & Navigation
- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

Radio Frequency Communications
- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

Position, Navigation, and Timing
- Timekeeping & Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Vision Processing Systems
- Relative & Proximity Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

Integrated Technologies
- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Navigation Sensors
- RF/Optical Hybrid Technology

Revolutionary Concepts
- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Nav. & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

Environmental Control & Life Support Systems & Habitation Systems
- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

Extravehicular Activity Systems
- Pressure Garment
- Portable Life Support System
- Power, Avionics & Software

Human Health & Performance
- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health
- Human Factors

Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology


TA07


TA08


TA09


TA10

TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

Sustainability & Supportability
- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

"Advanced" Human Mobility Systems
- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

"Advanced" Habitat Systems
- Integrated Habitat Systems
- Habitat Evolution
- "Smart" Habitats
- Artificial Gravity

Mission Operations & Safety
- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

Cross-Cutting Systems
- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

Remote Sensing Instruments/Sensors
- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

Observatories
- Mirror Systems
- Structures & Antennas
- Distributed Aperture

In-Situ Instruments/Sensor
- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

Descent
- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

Landing
- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

Vehicle Systems Technology
- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 · NANO-TECHNOLOGY

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

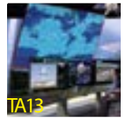
Energy Generation & Storage
- Energy Storage
- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments


TA11


TA12


TA13


TA14

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

Computing
- Flight Computing
- Ground Computing

Modeling
- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

Simulation
- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

Information Processing
- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies
- Collaborative Science & Engineering
- Advanced Mission Systems

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

Materials
- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

Structures
- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

Mechanical Systems
- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

Manufacturing
- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

Environmental and Green Technologies
- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Eco-systems
- Alternate Energy Prototypes

Technologies to Increase Reliability and Mission Availability
- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

Technologies to Improve Mission Safety/Mission Risk
- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics
- Safety Systems

TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

Thermal Control Systems
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY IMPACT

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To Be Determined
-

The effort to develop the STRs began in 2010 when NASA identified fourteen technology areas and then assigned agency specialists to describe their technology area's top technical challenges, the spaceflight missions they could impact or enable, and – as a byproduct – the important terrestrial fields they could advance. The set of draft STRs, which cover both human and robotic technologies, was distributed publicly in December 2010. At the same time, NASA contracted with the National Research Council (NRC) to perform an independent critique of the draft roadmaps. Through the NRC's participation, public comment was received, and independent expert panels subsequently reviewed the comments, established evaluation criteria, identified gaps, and prioritized the technologies within each technology area. An overall steering committee of the NRC then furtheprioritized across the technology areas, and released their final report early in 2012.

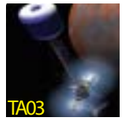
For any additional information:
NASA Space Technology Roadmaps

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

HUMAN SPACE FLIGHT TECHNOLOGY NEEDS*

National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS



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Unconventional / Other Propulsion Systems
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TA02 · IN-SPACE PROPULSION TECHNOLOGIES

Chemical Propulsion
- Liquid Storable
- Liquid Cryogenic
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- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

Non-Chemical Propulsion
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- Tether Propulsion

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- Breakthrough Propulsion

Supporting Technologies
- Propellant Storage & Transfer

TA03 · SPACE POWER & ENERGY STORAGE

Power Generation
- Energy Harvesting
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- Solar (Photo-Voltaic & Thermal)
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Energy Storage
- Batteries
- Flywheels
- Regenerative Fuel Cells

Power Management & Distribution
- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
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Cross Cutting Technology
- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 · ROBOTICS, TELE-ROBOTICS&AUTONOMOUS SYSTEMS

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RTA Systems Engineering
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TA05 · COMMUNICATION & NAVIGATION

Optical Comm. & Navigation
- Detector Development
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- Atmospheric Mitigation

Radio Frequency Communications
- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
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- Earth Launch & Reentry Comm.
- Antennas

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

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Radiation
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TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
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- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

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TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
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- Flexible Thermal Protection Systems
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Energy Generation & Storage
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- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

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Manufacturing
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Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
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TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
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- Integration & Modeling

Thermal Control Systems
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Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To be Determined
-

As the National Aeronautics and Space Administration (NASA) prepares to extend human presence throughout the solar system, technical capabilities must be developed to enable long duration flights to destinations such as near Earth asteroids, Mars, and extended stays on the Moon. As part of the NASA Human Spaceflight Architecture Team, a Technology Development Assessment Team has identified a suite of critical technologies needed to support this broad range of missions. Dialog between mission planners, vehicle developers, and technologists was used to identify a minimum but sufficient set of technologies, noting that needs are created by specific mission architecture requirements, yet specific designs are enabled by technologies. Further consideration was given to the re-use of underlying technologies to cover multiple missions to effectively use scarce resources. This suite of critical technologies is expected to provide the needed base capability to enable a variety of possible destinations and missions.

For the list of human spaceflight technology needs associated with the STR Technology Area Breakdown Structure. HAT- TABS Crosswalk

For additional details, background, and design reference mission context for the human space flight technology needs see: Critical Technology Determination for Future Human Space Flight

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

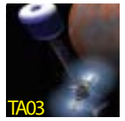
REVISED—12/20/12

* Can include Human Architecture Team, Human Research Program, International Space Station, Multi-Purpose Crew Vehicle, Science Mission Directorate, etc. technology needs in support of future NASA missions.

JSC CORE TECHNOLOGY COMPETENCIES

National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS



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Power Management & Distribution
- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

Cross Cutting Technology
- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 · ROBOTICS, TELE-ROBOTICS&AUTONOMOUS SYSTEMS

Sensing & Perception
- 3-D Perception
- Relative Position & Velocity Estimation
- Terrain Mapping, Classification & Characterization
- Natural & Man-made Object Recognition
- Sensor Fusion for Sampling & Manipulation
- Onboard Science Data Analysis

Mobility
- Extreme Terrain Mobility
- Below-Surface Mobility
- Above-Surface Mobility
- Small Body/Microgravity Mobility

Manipulation
- Robot Arms
- Dexterous Manipulators
- Modeling of Contact Dynamics
- Mobile Manipulation
- Collaborative Manipulation
- Robotic Drilling & Sample Processing

Human-Systems Integration
- Multi-Modal Human-Systems Interaction
- Supervisory Control
- Robot-to-Suit Interfaces
- Intent Recognition & Reaction
- Distributed Collaboration
- Common Human-Systems Interfaces
- Safety, Trust, & Interfacing of Robotic/ Human Proximity Operations

Autonomy
- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy
- Terrain Relative Navigation
- Path & Motion Planning with Uncertainty

Autonomous Rendezvous & Docking
- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces
- Mission/System Managers for Autonomy/Automation

RTA Systems Engineering
- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

Optical Comm. & Navigation
- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

Radio Frequency Communications
- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

Position, Navigation, and Timing
- Timekeeping & Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Vision Processing Systems
- Relative & Proximity Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

Integrated Technologies
- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Navigation Sensors
- RF/Optical Hybrid Technology

Revolutionary Concepts
- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Nav. & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

Environmental Control & Life Support Systems & Habitation Systems
- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

Extravehicular Activity Systems
- Pressure Garment
- Portable Life Support System
- Power, Avionics & Software

Human Health & Performance
- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health
- Human Factors

Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology

TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

Sustainability & Supportability
- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

"Advanced" Human Mobility Systems
- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

"Advanced" Habitat Systems
- Integrated Habitat Systems
- Habitat Evolution
- "Smart" Habitats
- Artificial Gravity

Mission Operations & Safety
- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

Cross-Cutting Systems
- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

Remote Sensing Instruments/Sensors
- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

Observatories
- Mirror Systems
- Structures & Antennas
- Distributed Aperture

In-Situ Instruments/Sensor
- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

Descent
- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

Landing
- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

Vehicle Systems Technology
- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 · NANO-TECHNOLOGY

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

Energy Generation & Storage
- Energy Storage
- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

Computing
- Flight Computing
- Ground Computing

Modeling
- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

Simulation
- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

Information Processing
- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies
- Collaborative Science & Engineering
- Advanced Mission Systems

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

Materials
- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

Structures
- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

Mechanical Systems
- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

Manufacturing
- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

Environmental and Green Technologies
- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Eco-systems
- Alternate Energy Prototypes

Technologies to Increase Reliability and Mission Availability
- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

Technologies to Improve Mission Safety/Mission Risk
- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics
- Safety Systems

TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

Thermal Control Systems
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To Be Determined
-

All NASA centers, based upon each center's unique qualifications, conduct research and technology developments to assure the long-term viability of America's space program. Each center's domain of technical excellence is based upon unique skills, personnel, and facilities that are aligned with the technology needs for NASA's aeronautics and science and human spaceflight missions. JSC's core technology competencies are directly tied to human exploration and include power generation, robotic manipulation and mobility systems, autonomous rendezvous and docking, radio frequency communications, position, navigation and timing technologies, environmental control and life support and habitation systems, human health and performance, radiation protection technologies, entry, descent and landing systems, modeling, simulation and information processing technologies, lightweight structures, mechanical systems, non-destructive evaluation, thermal control and thermal protection, and orbital debris and hypervelocity impact systems. The JSC Chief Technologist as well as the Center's technology management and development organizations assure that the Center's advanced technology planning, development, and infusion activities are strategically aligned with future NASA missions and programs.

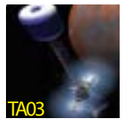
For any additional information, visit us at R&D Partnership Database (accessible to JSC employees only) or contact us by email at jsc-technology@mail.nasa.gov

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

PARTNERSHIP POTENTIAL – JSC PERSPECTIVE

National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS



TA01 · LAUNCH PROPULSION SYSTEMS

Solid Rocket Propulsion Systems
- Propellants
- Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

Liquid Rocket Propulsion Systems
- LH_2/LOX Based
- RP/LOX Based
- CH_4/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

Air Breathing Propulsion Systems
- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

Ancillary Propulsion Systems
- Auxiliary Control Systems
- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Sensors
- Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

Unconventional / Other Propulsion Systems
- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Assist
- Beamed Energy / Energy Addition
- Nuclear
- High Energy Density Materials/Propellants

TA02 · IN-SPACE PROPULSION TECHNOLOGIES

Chemical Propulsion
- Liquid Storable
- Liquid Cryogenic
- Gels
- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

Non-Chemical Propulsion
- Electric Propulsion
- Solar Sail Propulsion
- Thermal Propulsion
- Tether Propulsion

Advanced (TRL <3) Propulsion Technologies
- Beamed Energy Propulsion
- Electric Sail Propulsion
- Fusion Propulsion
- High Energy Density Materials
- Antimatter Propulsion
- Advanced Fission
- Breakthrough Propulsion

Supporting Technologies
- Propellant Storage & Transfer

TA03 · SPACE POWER & ENERGY STORAGE

Power Generation
- Energy Harvesting
- Chemical (Fuel Cells, Heat Engines)
- Solar (Photo-Voltaic & Thermal)
- Radioisotope
- Fission
- Fusion

Energy Storage
- Batteries
- Flywheels
- Regenerative Fuel Cells

Power Management & Distribution
- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

Cross Cutting Technology
- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 · ROBOTICS, TELE-ROBOTICS&AUTONOMOUS SYSTEMS

Sensing & Perception
- 3-D Perception
- Relative Position & Velocity Estimation
- Terrain Mapping, Classification & Characterization
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- Onboard Science Data Analysis

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- Distributed Collaboration
- Common Human-Systems Interfaces
- Safety, Trust, & Interfacing of Robotic/Human Proximity Operations

Autonomy
- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy
- Terrain Relative Navigation
- Path & Motion Planning with Uncertainty

Autonomous Rendezvous & Docking
- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces
- Mission/System Managers for Autonomy/Automation

RTA Systems Engineering
- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

Optical Comm. & Navigation
- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

Radio Frequency Communications
- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

Position, Navigation, and Timing
- Timekeeping & Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Vision Processing Systems
- Relative & Proximity Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

Integrated Technologies
- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Navigation Sensors
- RF/Optical Hybrid Technology

Revolutionary Concepts
- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Nav. & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

Environmental Control & Life Support Systems & Habitation Systems
- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

Extravehicular Activity Systems
- Pressure Garment
- Portable Life Support System
- Power, Avionics & Software

Human Health & Performance
- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health
- Human Factors

Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology

TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

Sustainability & Supportability
- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

"Advanced" Human Mobility Systems
- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

"Advanced" Habitat Systems
- Integrated Habitat Systems
- Habitat Evolution
- "Smart" Habitats
- Artificial Gravity

Mission Operations & Safety
- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

Cross-Cutting Systems
- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

Remote Sensing Instruments/Sensors
- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

Observatories
- Mirror Systems
- Structures & Antennas
- Distributed Aperture

In-Situ Instruments/Sensor
- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

Descent
- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

Landing
- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

Vehicle Systems Technology
- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 · NANO-TECHNOLOGY

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

Energy Generation & Storage
- Energy Storage
- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

Computing
- Flight Computing
- Ground Computing

Modeling
- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

Simulation
- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

Information Processing
- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

Materials
- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

Structures
- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

Mechanical Systems
- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

Manufacturing
- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

Environmental and Green Technologies
- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Ecosystems
- Alternate Energy Prototypes

Technologies to Increase Reliability and Mission Availability
- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

Technologies to Improve Mission Safety/Mission Risk
- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics

TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

Thermal Control Systems
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To be Determined
-

Our experience in space exploration benefits life on earth. NASA has many capabilities and assets that may be applicable to your industry. Whether you are working in commercial space, aerospace or non-aerospace industries, we want to pursue collaborative partnerships in R & D, advanced technology and new technology applications. We invite you to explore Johnson Space Center's world-class expertise and capabilities, including an established infrastructure, unique engineering facilities, integrated project management, safety and risk analysis, human habitability, health and performance expertise, and proven design, development, testing and operation of complex systems designed for extreme environments. We are committed to helping you leverage our expertise and capabilities to meet your goals.

Contact the JSC Strategic Opportunities and Partnership Development Office by phone ***281-483-3000*** or jsc-partnerships@mail.nasa.gov by email to begin a conversation about your interests. For information visit: JSC Human Spaceflight Capabilities

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

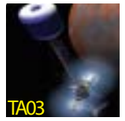
COMMERCIALIZATION POTENTIAL – JSC PERSPECTIVE

National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS


TA01


TA02


TA03


TA04


TA05


TA06

TA01 · LAUNCH PROPULSION SYSTEMS

Solid Rocket Propulsion Systems
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Liquid Rocket Propulsion Systems
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Unconventional / Other Propulsion Systems
- Ground Launch Assist
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- Space Tether Assist
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- Nuclear
- High Energy Density Materials/Propellants

TA02 · IN-SPACE PROPULSION TECHNOLOGIES

Chemical Propulsion
- Liquid Storable
- Liquid Cryogenic
- Gels
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Non-Chemical Propulsion
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- Propellant Storage & Transfer

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Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology


TA07


TA08


TA09


TA10

TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

Sustainability & Supportability
- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

"Advanced" Human Mobility Systems
- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

"Advanced" Habitat Systems
- Integrated Habitat Systems
- Habitat Evolution
- "Smart" Habitats
- Artificial Gravity

Mission Operations & Safety
- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

Cross-Cutting Systems
- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

Remote Sensing Instruments/Sensors
- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

Observatories
- Mirror Systems
- Structures & Antennas
- Distributed Aperture

In-Situ Instruments/Sensor
- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

Descent
- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

Landing
- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

Vehicle Systems Technology
- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 · NANO-TECHNOLOGY

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

Energy Generation & Storage
- Energy Storage
- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments


TA11


TA12


TA13


TA14

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

Computing
- Flight Computing
- Ground Computing

Modeling
- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

Simulation
- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

Information Processing
- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies
- Collaborative Science & Engineering
- Advanced Mission Systems

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

Materials
- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

Structures
- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

Mechanical Systems
- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

Manufacturing
- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

Environmental and Green Technologies
- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Eco-systems
- Alternate Energy Prototypes

Technologies to Increase Reliability and Mission Availability
- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

Technologies to Improve Mission Safety/Mission Risk
- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics
- Safety Systems

TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

Thermal Control Systems
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY IMPACT

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To Be Determined
-

The Technology Transfer and Commercialization Office at NASA's Johnson Space Center (JSC) facilitates the transfer and commercialization of NASA-sponsored research and technology as well as the use of JSC's unique research and development capabilities and facilities. The office works with entrepreneurs, companies, and investors, helping them license NASA-developed technologies so they can bring them to the marketplace. We actively market technologies that show a high degree of potential, creating appropriate promotional collateral, seeking out prospective licensees, and negotiating win-win deals. NASA patent licenses may be exclusive, co-exclusive, partially exclusive, or non-exclusive.

For more information contact us by calling **281-483-3809**, sending email to jsc-techtran@mail.nasa.gov or visiting us on the web at: JSC Technology Transfer

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

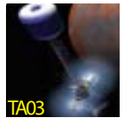
REVISED—12/20/12

Note: Evaluation is based upon competitive, commercial market potential over next decade and thus must demonstrate unique value and advance state of the art in a commercial market

AREAS OF SIGNIFICANT OVERLAP*

National Aeronautics and Space Administration

OFFICIAL NASA ROADMAPS



TA01 · LAUNCH PROPULSION SYSTEMS

Solid Rocket Propulsion Systems
- Propellants
- Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies

Liquid Rocket Propulsion Systems
- LH_2/LOX Based
- RP/LOX Based
- CH_4/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

Air Breathing Propulsion Systems
- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

Ancillary Propulsion Systems
- Auxiliary Control Systems
- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Sensors
- Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

Unconventional / Other Propulsion Systems
- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Assist
- Beamed Energy / Energy Addition
- Nuclear
- High Energy Density Materials/Propellants

TA02 · IN-SPACE PROPULSION TECHNOLOGIES

Chemical Propulsion
- Liquid Storable
- Liquid Cryogenic
- Gels
- Solid
- Hybrid
- Cold Gas/Warm Gas
- Micro-propulsion

Non-Chemical Propulsion
- Electric Propulsion
- Solar Sail Propulsion
- Thermal Propulsion
- Tether Propulsion

Advanced (TRL <3) Propulsion Technologies
- Beamed Energy Propulsion
- Electric Sail Propulsion
- Fusion Propulsion
- High Energy Density Materials
- Antimatter Propulsion
- Advanced Fission
- Breakthrough Propulsion

Supporting Technologies
- Propellant Storage & Transfer

TA03 · SPACE POWER & ENERGY STORAGE

Power Generation
- Energy Harvesting
- Chemical (Fuel Cells, Heat Engines)
- Solar (Photo-Voltaic & Thermal)
- Radioisotope
- Fission
- Fusion

Energy Storage
- Batteries
- Flywheels
- Regenerative Fuel Cells

Power Management & Distribution
- FDIR
- Management & Control
- Distribution & Transmission
- Wireless Power Transmission
- Conversion & Regulation

Cross Cutting Technology
- Analytical Tools
- Green Energy Impact
- Multi-functional Structures
- Alternative Fuels

TA04 · ROBOTICS, TELE-ROBOTICS&AUTONOMOUS SYSTEMS

Sensing & Perception
- 3-D Perception
- Relative Position & Velocity Estimation
- Terrain Mapping, Classification & Characterization
- Natural & Man-made Object Recognition
- Sensor Fusion for Sampling & Manipulation
- Onboard Science Data Analysis

Mobility
- Extreme Terrain Mobility
- Below-Surface Mobility
- Above-Surface Mobility
- Small Body/Microgravity Mobility

Manipulation
- Robot Arms
- Dexterous Manipulators
- Modeling of Contact Dynamics
- Mobile Manipulation
- Collaborative Manipulation
- Robotic Drilling & Sample Processing

Human-Systems Integration
- Multi-Modal Human-Systems Interaction
- Supervisory Control
- Robot-to-Suit Interfaces
- Intent Recognition & Reaction
- Distributed Collaboration
- Common Human-Systems Interfaces
- Safety, Trust, & Interfacing of Robotic/ Human Proximity Operations

Autonomy
- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy
- Terrain Relative Navigation
- Path & Motion Planning with Uncertainty

Autonomous Rendezvous & Docking
- Relative Navigation Sensors (long-, mid-, near-range)
- Guidance Algorithms
- Docking & Capture Mechanisms/Interfaces
- Mission/System Managers for Autonomy/Automation

RTA Systems Engineering
- Modularity/Commonality
- Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

Optical Comm. & Navigation
- Detector Development
- Large Apertures
- Lasers
- Acquisition & Tracking
- Atmospheric Mitigation

Radio Frequency Communications
- Spectrum Efficient Technologies
- Power Efficient Technologies
- Propagation
- Flight & Ground Systems
- Earth Launch & Reentry Comm.
- Antennas

Internetworking
- Disruptive Tolerant Networking
- Adaptive Network Topology
- Information Assurance
- Integrated Network Management

Position, Navigation, and Timing
- Timekeeping & Time Distribution
- Onboard Auto Navigation & Maneuver
- Sensors & Vision Processing Systems
- Relative & Proximity Navigation
- Auto Precision Formation Flying
- Auto Approach & Landing

Integrated Technologies
- Radio Systems
- Ultra Wideband
- Cognitive Networks
- Science from the Comm. System
- Hybrid Optical Comm. & Navigation Sensors
- RF/Optical Hybrid Technology

Revolutionary Concepts
- X-Ray Navigation
- X-Ray Communications
- Neutrino-Based Nav. & Tracking
- Quantum Key Distribution
- Quantum Communications
- SQIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

Environmental Control & Life Support Systems & Habitation Systems
- Air Revitalization
- Water Recovery & Management
- Waste Management
- Habitation

Extravehicular Activity Systems
- Pressure Garment
- Portable Life Support System
- Power, Avionics & Software

Human Health & Performance
- Medical Diagnosis / Prognosis
- Long-Duration Health
- Behavioral Health
- Human Factors

Environmental Monitoring, Safety & Emergency Response
- Sensors: Air, Water, Microbial, etc.
- Fire: Detection, Suppression, Recovery
- Protective Clothing / Breathing
- Remediation

Radiation
- Risk Assessment Modeling
- Radiation Mitigation
- Protection Systems
- Radiation prediction
- Monitoring Technology

TA07 · HUMAN EXPLORATION DESTINATION SYSTEMS

In-Situ Resource Utilization
- Destination Reconnaissance, Prospecting, & Mapping
- Resource Acquisition
- Consumables Production
- Manufacturing Products & Infrastructure Emplacement

Sustainability & Supportability
- Autonomous Logistics Management
- Maintenance Systems
- Repair Systems
- Food Production, Processing, & Preservation

"Advanced" Human Mobility Systems
- EVA Mobility
- Surface Mobility
- Off-Surface Mobility

"Advanced" Habitat Systems
- Integrated Habitat Systems
- Habitat Evolution
- "Smart" Habitats
- Artificial Gravity

Mission Operations & Safety
- Crew Training
- Planetary Safety
- Integrated Flight Operations Systems
- Integrated Risk Assessment Tools

Cross-Cutting Systems
- Construction & Assembly
- Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

Remote Sensing Instruments/Sensors
- Detectors & Focal Planes
- Electronics
- Optical Components
- Microwave / Radio
- Lasers
- Cryogenic / Thermal

Observatories
- Mirror Systems
- Structures & Antennas
- Distributed Aperture

In-Situ Instruments/Sensor
- Particles: Charged & Neutral
- Fields & Waves
- In-Situ

TA09 · ENTRY, DESCENT & LANDING SYSTEMS

Aeroassist & Atmospheric Entry
- Rigid Thermal Protection Systems
- Flexible Thermal Protection Systems
- Rigid Hypersonic Decelerators
- Deployable Hypersonic Decelerators

Descent
- Attached Deployable Decelerators
- Trailing Deployable Decelerators
- Supersonic Retropropulsion

Landing
- Touchdown Systems
- Egress & Deployment Systems
- Propulsion Systems
- Small Body Systems

Vehicle Systems Technology
- Separation Systems
- System Integration and Analyses
- Atmosphere & surface characterization
- Modeling and Simulation
- Instrumentation and Health Monitoring
- GN&C Sensors and Systems

TA10 · NANO-TECHNOLOGY

Engineered Materials & Structures
- Lightweight Structures
- Damage Tolerant Systems
- Coatings
- Adhesives
- Thermal Protection & Control

Energy Generation & Storage
- Energy Storage
- Energy Generation

Propulsion
- Propellants
- Propulsion Components
- In-Space Propulsion

Sensors, Electronics & Devices
- Sensors & Actuators
- Nanoelectronics
- Miniature Instruments

TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

Computing
- Flight Computing
- Ground Computing

Modeling
- Software Modeling & Model-Checking
- Integrated Hardware & Software Modeling
- Human-System Performance Modeling
- Science Modeling
- Frameworks, Languages, Tools & Standards

Simulation
- Distributed Simulation
- Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering
- Simulation-Based Training & Decision Support Systems

Information Processing
- Science, Engineering & Mission Data Lifecycle
- Intelligent Data Understanding
- Semantic Technologies
- Collaborative Science & Engineering
- Advanced Mission Systems

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

Materials
- Lightweight Structure
- Computational Design
- Flexible Material Systems
- Environment
- Special Materials

Structures
- Lightweight Concepts
- Design & Certification Methods
- Reliability & Sustainment
- Test Tools & Methods
- Innovative, Multifunctional Concepts

Mechanical Systems
- Deployables, Docking and Interfaces
- Mechanism Life Extension Systems
- Electro-mechanical, Mechanical & Micromechanisms
- Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring
- Certification Methods

Manufacturing
- Manufacturing Processes
- Intelligent Integrated Manufacturing and Cyber Physical Systems
- Electronics & Optics Manufacturing Process
- Sustainable Manufacturing

Cross-Cutting
- Nondestructive Evaluation
- Model-Based Certification & Sustainment Methods
- Loads and Environments

TA13 · GROUND & LAUNCH SYSTEMS PROCESSING

Technologies to Optimize the Operational Life-Cycle
- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground Systems

Environmental and Green Technologies
- Corrosion Prevention, Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Eco-systems
- Alternate Energy Prototypes

Technologies to Increase Reliability and Mission Availability
- Advanced Launch Technologies
- Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Identification
- Fault Isolation and Diagnostics
- Prognostics Technologies
- Repair, Mitigation, and Recovery Technologies
- Communications, Networking, Timing & Telemetry

Technologies to Improve Mission Safety/Mission Risk
- Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components
- Weather Prediction and Mitigation
- Robotics / Telerobotics
- Safety Systems

TA14 · THERMAL MANAGEMENT SYSTEMS

Cryogenic Systems
- Passive Thermal Control
- Active Thermal Control
- Integration & Modeling

Thermal Control Systems
- Heat Acquisition
- Heat Transfer
- Heat Rejection & Energy Storage

Thermal Protection Systems
- Entry / Ascent TPS
- Plume Shielding (Convective & Radiative)
- Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY

Orbital Debris
- Modeling
- Monitoring
- Mitigation
- Remediation

Hypervelocity Impact
- Material Composition
- Experimental Investigations

TA17 · EMERGING TECHNOLOGIES

To be Determined
-

These "Areas of Significant Overlap" highlight the overlaps between weighted priorities identified in these "prioritization charts". The JSC Technology Working Group (JTWG) determined the weighting factors that should be associated with each of the four sets of priorities as follows:

Human Space Flight (HSF) Needs (pg. 2)	0.4
JSC Technology Competencies (pg. 3)	0.4
Partnership Potential (pg. 4)	0.1
Commercialization Potential (pg. 5)	0.1

Each technical area in the Space Technology Roadmap Technology Area Breakdown Structure (TABS) was assigned a raw score (high priority = 0.9, medium priority = 0.3, low priority = 0.1) which was multiplied by the weights for each of the four priority areas. Overlap scores were computed by summing the four weighted scores for each TABS area. For example, the TA06 Human Health, Life Support & Habitation Systems / Radiation / Monitoring Technology area was assigned the following raw scores:

HSF Technology Needs	0.9
JSC Core Technology Competencies	0.3
Partnership Potential	0.3
Commercialization Potential	0.0

The Overlap score for the Monitoring Technology area was calculated to be: 0.9 x 0.4 + 0.3 x 0.4 + 0.3 x 0.1 + 0.0 x 0.0 = 0.51. A specified number of TABS areas with the highest Overlap scores were selected to create this Areas of Significant Overlap chart.

Space Technology Roadmaps (STRs)
TECHNOLOGY AREA BREAKDOWN STRUCTURE

REVISED—12/20/12

* Highlighted areas represent highly-rated intersections between TABS and Needs, Competencies/Project Focus, and Commercial/ Partnership Potential.